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LEAD-TIME IN MODERN WEAPONS

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Many people seem puzzled by our inability to launch a satellite the day after Sputnik and see each passing month as a measure of U.S. inadequacy. Without in any way touching either scientific or national security matters, this paper deals with the fundamental reason for this situation--LEAD-TIME or the weeks to years required for the administrative and physical actions in translating wanting into getting. The present picture surely presents one thing--we did not decide to launch a satellite early enough. It does not necessarily mean we are behind in anything more than that.

The experience should teach us a few things. Among them: the importance of LEAD-TIME; continuity of effort, even on a relatively small scale, buys more than spasmodic large bursts; and there are some things for which money cannot fully substitute, like time. All of that is again a way of saying "LEAD-TIME."

It seems strange that it is so difficult to explain the importance and the length of the lead-time in research, development, procurement and production of military aircraft and guided missiles when everyone is familiar with the long lapse of time that separates the writing of a contract from the completion of buildings we see in civil life. Take a medium-sized city office structure, say ten or fifteen stories tall. From the time that an owner-to-be signs his name to a contract until he

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takes possession a year, a year and a half, two years or more may elapse without anyone considering the delay at all remarkable.

A big, modern office building is an impressive addition to a local community but it is not an accomplishment that anyone would propose to measure in terms like those to be applied to Sputniks, ICBM's and space travel equipment. Raising the capital to pay for a big office building may not be exactly easy but the details rarely receive the attention given budget proposals for advanced military equipment.

An office building is not a very complicated structure, in comparison with modern military aircraft and guided missiles. Standard grades of steel are used for beams, reinforcement rods and mesh. A large number of suppliers stand ready to sell ready-mixed concrete, sheathing materials for the exterior, sash, flooring, roofing materials, and every other part of the structure. The most complicated items in the structure probably are the elevator and air conditioning systems. Still it takes a year to two years or more to complete an office building.

Contrast this with the design and construction of a new kind of military aircraft or guided missile. If the military item is to fulfill the expectations of its designers, it must outperform anything existing and hence the engineer must go beyond his own experience or the experience of anyone else. The money market problem is different, too. The need for the new aircraft or missile must be justified to eight or ten echelons of executives, first military and then civilian. If it survives this review it might, by chance, be just in time when the federal money market--budget appropriations--is open, once a year. If design should be delayed or if review is too protracted, the money market may be closed and no important

action toward funding it can be taken for another year. At that time, it will have to compete with other designs for available funds.

The steel used in its construction does not come from stock. The great structural strength at temperatures approaching white heat needed in high-performance engines requires special steel alloys that are mixed and melted to order. The words "special" or "made to order" have to be applied to almost everything that enters into the construction of modern, high-performance military vehicles. Nothing can be pieced together, cut-and-try; the weight and performance dimensions of every component have to be computed long before construction begins.

An engineer designing military equipment might object to what I'm saying on the ground that it understates the great differences in level of difficulty in designing and constructing a large but simple structure, like an office building, as contrasted to a large, precision-made, complicated structure like a modern military aircraft or guided missile. He would be right; I have understated the differences. I have also failed to explain how these differences in level of difficulty create differences in the time required to solve the technical problems involved. This will always be nearly impossible to explain in words; to demonstrate these propositions properly would require a behind-the-scenes tour.

I'll have to be satisfied if I can persuade you that if great patience is needed in awaiting the completion of a simple structure like an office building, even greater patience will be needed awaiting the completion of the first military aircraft or guided missile of a new series. Neither of them can be had off-the-shelf today just because we want them now.

Modern military demands are complex and the processes of satisfying them are complicated and time consuming. Over the last century the number

of steps and length of time required for the fabrication of complete products has increased many fold. The machine-to-make-the-machine has played an increasingly important role in our method of production. Specialization, mechanization, and automation, characterize modern industry, and although they speed up the processes and increase the output at the point of final assembly, if we go back a few steps in the method we immediately encounter time-consuming and investment-demanding requirements.

These problems shift the burden from an individual supplier to the total economic system and make long periods of time necessary for the accomplishment of tasks. When we stand at the end of an assembly line in an automobile or washing machine plant, we see only the large volume of finished products turned out each day. The same thing would be true at an aircraft factory or tank arsenal. In any of these cases, what we see is the pinnacle of a huge pyramid of effort which brings purchased materials, machinery, and parts together. Each one of these components is in itself a small pyramid constructed from the tops of innumerable other pyramids of production.

THE TIME DIMENSION

We lose sight of the size of the pyramid at the point of final assembly and are almost unaware of the pyramidal structures involved at each succeedingly lower layer. The final product has a time as well as quantity and quality dimensions and each of the sub-pyramids has in itself a major time dimension. Since it is impossible to erect any one of them without the appropriate foundation, the time measure must be applied not only to the apex of the pyramid, but also to each one of the building blocks which support the final product.

We are made aware of both the long-time and investment-demanding nature of modern production by announcements like a five-year, billion dollar plan for investment by an auto maker; an eight-year program involving $600 million for the expansion of an oil company. However, we rarely have an occasion to translate these magnitudes of time into the automobile or gasoline which we use. We expect the automobile to be on view and ready for delivery from the dealer's window, and we know that we can get the gasoline for it at the nearest pump. As a result, we find it hard to take into account the years that went into the accomplishment of the delivery which for us is a matter of moments.

We get a real taste of the lead-time process when we undertake to repair or build a house. Particularly if we build for our own account and start with the acquisition of the lot, the drawing of the plans, the letting of the contracts, and so on until the day of occupancy. That experience makes us aware of the five to eighteen months involved in the process. Nonetheless, we tend to view it as something special and do not draw an analogy from that experience to the time required for making automobiles and washing machines and never apply it to equipment like military aircraft and missiles.

A moment's reflection will make us immediately aware of how very simple a house is when compared to a ballistic missile. Even the latest and most radical improvements in house design or equipment represent a small change from yesterday when compared with ballistic missiles which are just now being created for the first time. V-2's were used by the Germans more than a decade ago. The fact that they are new to the arsenals of the U.S. and U.S.S.R. in 1958 is in itself a major measure of the

nature and span of lead-time. In the ballistic missile the newness is striking and leads us to forget that the changes in aircraft, guns and vehicles are almost equall great. Even the newest color television set represents a minute step forward in comparison with the economic and time dimensions in equipment for today's soldiers.

THE RESEARCH DIMENSION

In large measure the improvements in today's products are innovations rather than inventions. That is, the new idea was researched and invented many years ago; the thing that is new to us represents development and application of an old idea as identified in comparing the V-2 to the IRBM and ICBM.

The point can be easily made for those who can recall the push-button or automatic gear-shift of the Mitchell and Premier automobiles which were on the road around 1920. It was twenty-five years or so before those ideas were developed for general application to passenger automobiles. Much the same history applies to electric appliances, radio, television, building materials, etc.

Research and new ideas are important in all products and processes, but in the non-military field there is a very real requirement to prove-out the idea and test the market before going into production. In the military field, ability to "surprise the enemy" or "not be surprised by him" is paramount, so new ideas must be continuously sought and brought into production without opportunity to prove-out the fabrication and operation problems.

Military requirements therefore must have a much broader research base than is required for commercial products. The activities must include not

only new ways of doing a job--aircraft, missiles, vehicles, etc.--but also all of the materials, components and processes involved in producing the new devices. In all of these, continuity is a paramount consideration lest a research discovery in one field be too far ahead of the essential supporting fields to permit the quick development and application of the new idea.

DEVELOPMENT AND APPLICATION

New scientific discoveries or inventions usually are just the beginning of a large number of steps required first in developing a product and then finding ways of applying the invention to either established or new ways of doing the job. Again, a bit of history may facilitate exposition. At the Columbian Exposition a primitive zipper was displayed. By 1912, patents on the modern zipper had been granted in England, Belgium, Switzerland and the U.S. World War I doughboys bought several million zipper money belts. Yet it was not until 1940 and later that zippers came into widespread use on both consumer and industrial products.

One's first reaction to the time it took to get the zipper into widespread use are either lack of financing, salesmanship or other commercial and financial considerations. Those factors played a small role, but most of the years were required for product development and application engineering. And, product development and application engineering are practically always major factors in getting from discovery to utilization.

In possible new military products the time required must be made as short as possible. Shortening it requires men and resources, but it is important to remember that no matter how much money is spent it still takes time. As in the case of research, continuity of effort is a prerequisite if the time requirement is to be kept reasonably short.

PRODUCTION

Just as scientific discovery or invention is the prelude to development and application engineering, so also the successful completion of the second set of steps is just the beginning of the manufacturing process. The opening paragraphs referred to the five to eighteen months required from start to finish for a private residence. Let us now take an over-simplified look at the time and integration requirements for a modern new commercial airplane. Bear in mind that research, development, and product engineering time are not included.

Once production has been started, delivery can be made in a year or two. But, the start of production requires two or more added years. Many of the tools take six months or more for design and as much additional time in fabrication. High specification materials, formed in special shapes, require as much as a year and sometimes more for initial deliveries. These are typical of the items which go into the years preceding production. And since the final product is the sum of its parts, the item with the longest lead-time will set the absolute minimum time for final delivery. Men, money and desire can speed things up, but in the end there is a fundamental physical requirement for time. In equipment like transport aircraft, it would be a fortunate situation indeed in which the procedure could get this below two years.

Some idea of the magnitude of things to be done may be had from Chart I. That illustration emphasizes a relatively simple and small part of one of the newest jet transports. Applying one's imagination to that illustration will provide one measure of the magnitude of the total job involved.

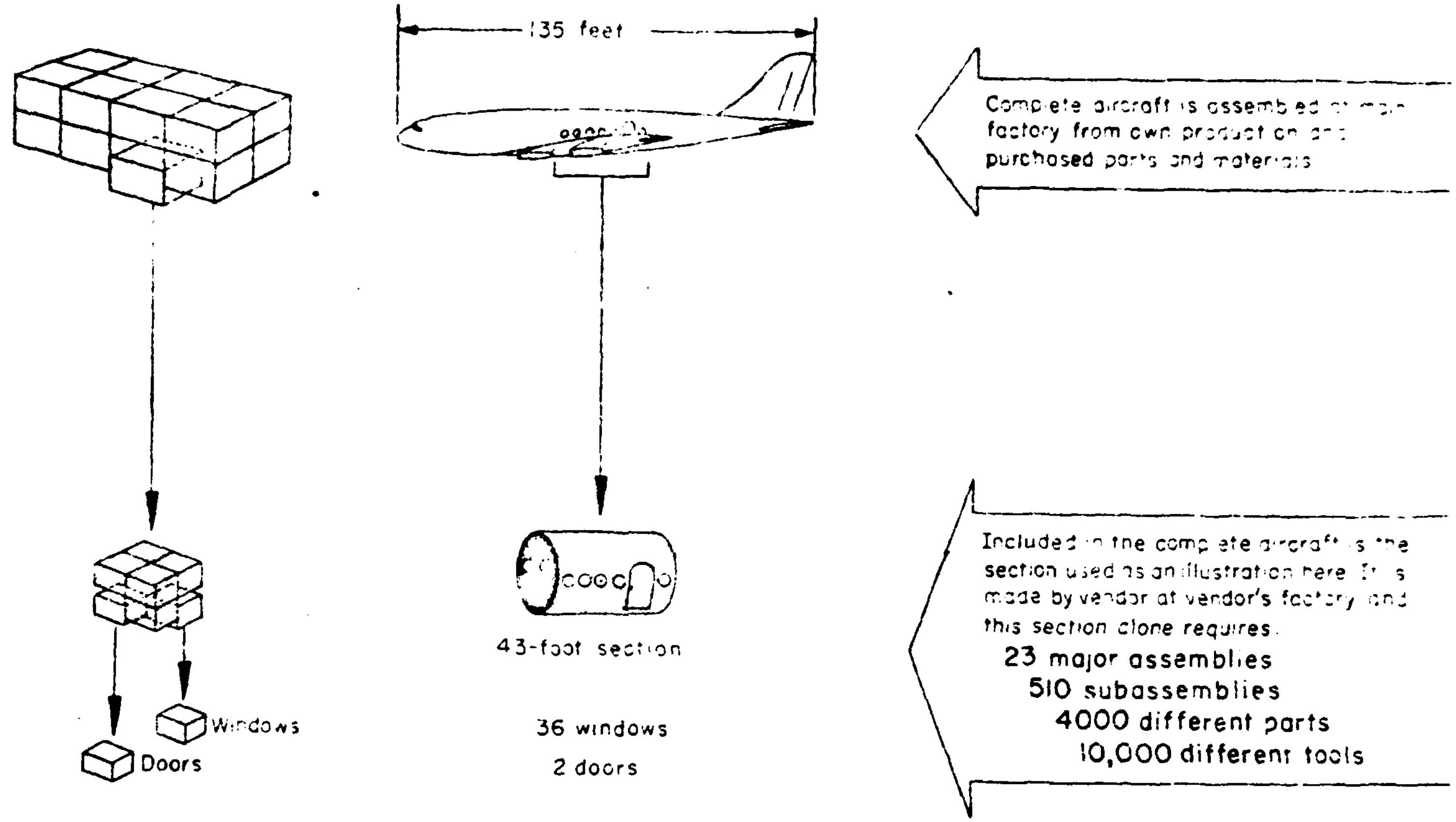

Chart I — Building-block relationship in production of commercial jet transport

The document discusses lead time in this

SIMPLE ADDITION

Using these over-simplified illustrations, we can now project an absolute minimum time requirement for getting new military equipment embodying the latest scientific developments, requiring time for

Basic Research,

Assumed to be continuous and therefore not included in this time charge. If the basic research effort is NOT adequate, the time penalty is likely to be immense.

Product Research,

Again, it is assumed that research in materials, components processes and tools is continuous and adequate. Given that favorable assumption, TWO YEARS would be an absolute minimum; THREE to FIVE YEARS more likely for advanced equipment.

Product Development,

With luck, this time requirement might be held within the research cycle, but it is more likely to mean at least ONE YEAR more.

Application Engineering,

For refinements of existing equipment this need not be an added time demand. For revolutionary new equipment, ONE YEAR more would be a minimum.

Manufacturing.

Assuming no additions to plant and equipment, TWO YEARS would be a short time to get into production.

Table I

New Equipment Steps and Time Required in Years

	Basic Research	Product Research	Product Development	Application Engineering	Manufacturing	Total
Optimistic	0	2	1	1	2	3-6
Possible	0	3	2	2	2	5-9
More Likely	0	4	4	2	3	8-13

Exceptions to the above can be cited, both wherein less time than the "Optimistic" illustration and many more years than the "More Likely" number were required. Precise accuracy is neither possible nor an objective here. If this play on steps involved and time to take them conveys the idea that military equipment involving new inventions or discoveries requires something more than money, the point will have been made. It takes years, too.

THE GOVERNMENT MONEY DIMENSION

For the military to get the new equipment, another time factor must be taken into account--government procedure for approving expenditures or the federal budget. Probably nothing seems more simple and obvious and then turns out to be more complex and mysterious than the process by which the United States Government grants authority for a military department to spend money. Since the time to get new military equipment is our interest here, let us neglect the procedure and emphasize only the effect this requirement has on the number of years involved.

Assuming adequate research in the basic sciences, the first step is product research or the design of equipment which will utilize the promises of basic research. Although not large of itself, when the fruits of science become as plentiful and expensive as they are today, the quantity of funds traditionally made available becomes inadequate. If we start today in 1958 we can increase funds in the budget for fiscal year 1959.

Even though the make-ready is relatively simple in this area, competent personnel must be found, hired, moved to the work place and put through the security clearance process. All of that takes time--a year would be good going. If competent management is available and has space, equipment, supervisory employees, etc., that time requirement may not be encountered. But, if new sources of capability are to be added, something like another year should be added. In short, if Congress acts by July, 1958 we can expect things to get underway by summer 1959, with luck, and by early 1960 under more usual conditions.

The foregoing failed to take into account the time necessary to get the proposal before Congress. It was omitted because it was assumed that in a "crisis," like the present one, normal procedure would be waived.

Under standard operating procedure the item on which Congress acts in 1958 had to originate in the lower echelons of the sponsoring military department about two years earlier. From its inception, it would have travelled up a series of review steps until incorporated in the department's budget. Even when on the top of this ladder, a cut in department budget could either curtail or eliminate the amount for the item.

The military department's budget proposal then moves to inclusion in the Department of Defense proposal. Again, the item may be cut or eliminated

specifically or become a casualty in an over-all departmental cut. A similar process then takes place when the Department of Defense proposal is presented to the Bureau of the Budget. It is repeated once again at the President's review which for our fiscal year 1959 item was at the end of 1957.

From the foregoing, one may picture both the possibility of adoption and the time required in getting new concepts from the idea to the accomplishment stage. Although not strictly additive, the same time requirement can be applied to the government time dimension for each of the major steps in Table I.

Discussions of government spending are always confused by lack of precise distinction between NOA and Expenditures. They are two different things:

New Obligating Authority - The Right to Spend

Treasury Expenditures - The Actual Disbursement

Differences in timing for each for major equipment requirements for a military department are shown in Chart II. Time lag becomes identifiable when one observes the Korea crisis budget expansion in FY 1951 and 1952 against the expenditure peak in 1954 and 1955. Again, the 1954 and 1955 budget balancing exercises produce the downturn in FY 1956 and 1957 deliveries despite the higher amount of new obligating authority granted in those years.

STOP-THEN-START, START-THEN-STOP

At the time of the Korean difficulty, we reacted as though World War III might be starting, and that produced major changes in the New Obligating Authority budget. These and expenditures in fiscal years 1950 through

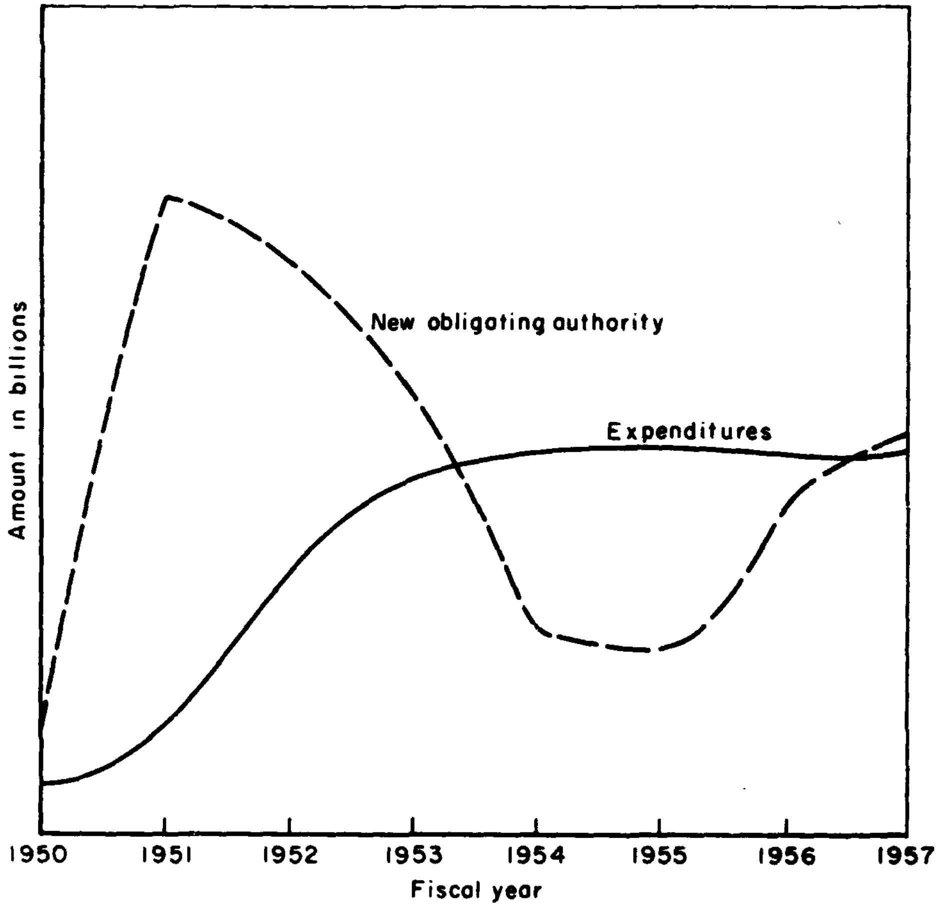

Chart II — Comparison of military equipment new obligating authority and expenditures by fiscal years 1950 through 1957

Source: Federal Budget Documents 1950 through 1956; 1957 estimated

1957 are shown in Chart III. As the curves show, expenditures lagged substantially behind the granting of authority to spend at first, and later expenditures moved to the front. If these data are compared with Chart II, it will be noted that the rate-of-change is not the same in both cases. That occurs because Chart III covers every and all kinds of expenditures, including pay and subsistence, and Chart II is major equipment only. Lead-time is a major factor in military equipment; it is much shorter in the case of military manpower expenditures.

Getting back to Chart III, we can see the impact of the Korean armistice in July, 1953 on FY 1954 and 1955 New Obligating Authority and Expenditures. At this point it is important to go back to Chart II which treats of major equipment only. It will be noted that equipment expenditures continued higher in 1954 and 1955 despite cuts in NOA just as they expanded slowly in 1951 and 1952 when NOA was increased sharply. Both of these situations are the result of lead-time. Time required to get production underway is well illustrated by the 1951 through 1954 pattern. It is what we can expect again in 1959 through 1961.

To be sure, we start from a higher base now, but the rate of acceleration in finished articles will follow the same expansion pattern if we buy goods that have been researched and developed. If we vote to expand research and development, we can anticipate a similar expansion pattern regardless of how much money is appropriated. Knowing it gets monotonous, I nonetheless am forced to repeat--money cannot be fully substituted for time.

When we start, as we did in FY 1951, it takes time to get going. When we stop, as we did in 1953, it takes time to bring things into order for the slow-down. When we start-then-stop and stop-then-start as we

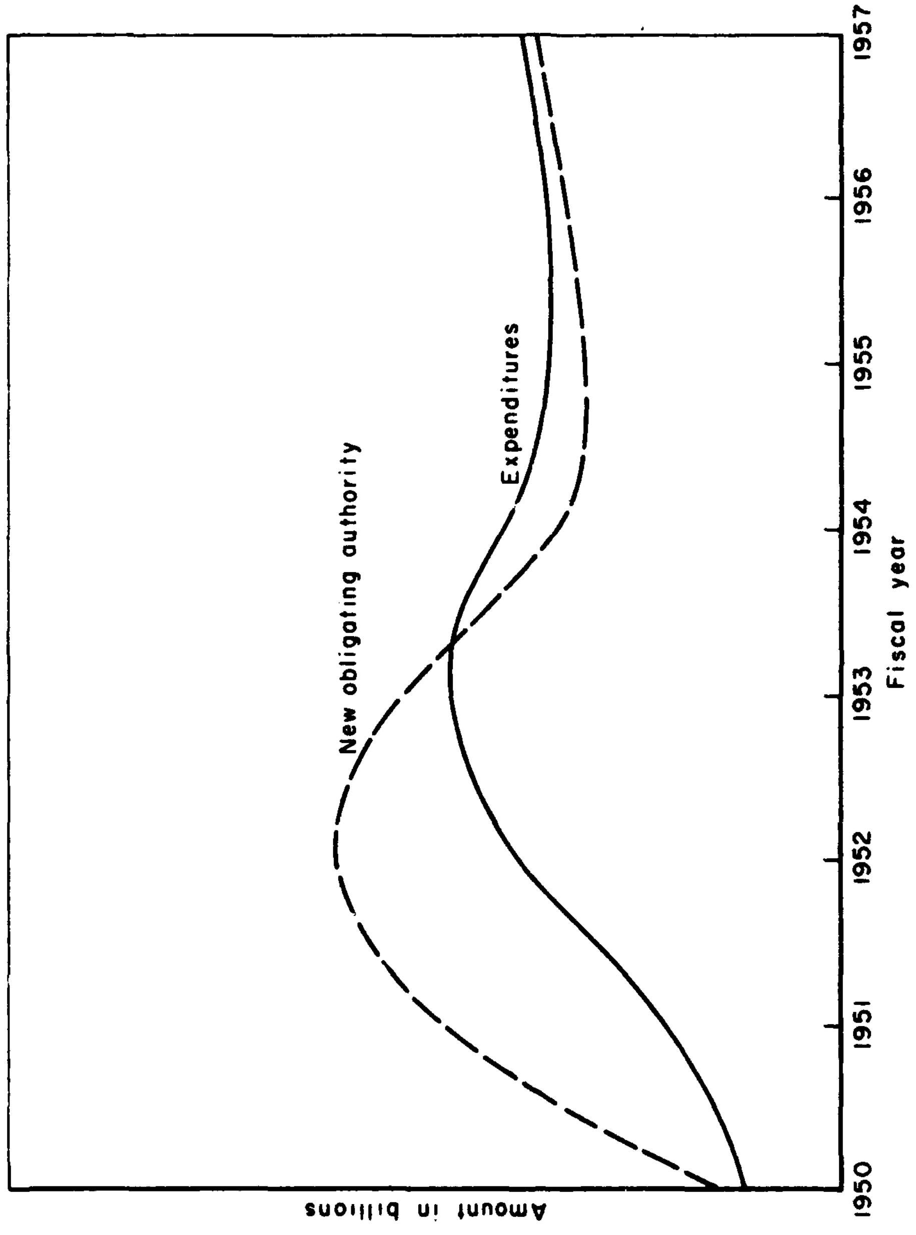

Chart III — Comparison of total new obligating authority and total expenditures for Dept. of Defense by fiscal years 1950 through 1957

Source: Federal Budget Documents

have been doing since 1950, we shake, jostle, and jolt our entire productive process from laboratory through factory. The resulting economic costs are very real and the effect on personnel in military, government, industry and scientific pursuits borders on the catastrophic.

Professor Smithies (Harvard) summed it up in recent testimony before this Committee. " . . . something is wrong with our method of budgeting for defense. The root of the trouble is that political democracies have not yet learned to make the sustained defense efforts that are now needed. While this may be in part an inevitable price we must pay for democracy, these are various features of the budgetary process that contribute to the lack of support for an adequate defense effort.

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"The present procedures grow out of the requirements of an earlier and simpler period of military history. If the Army consists mainly of armed soldiers, the budget can be considered in terms of the number of soldiers, and supplies, arms, and ammunition per soldier. That still remains the central idea in present budgetary procedure, however inappropriate it may be in the day of the hydrogen bomb and the ballistic missile."*

CONCLUSION

Military equipment today must embody not only the latest development efforts of our laboratories, but also must be projected in terms of the most promising results now being made available by research. That means producing and learning to use complex advance equipment which imposes a

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*Arthur Smithies, "The Defense Budget," Joint Economic Committee, 85th Congress, 1st Session, November 5, 1957, Federal Expenditure Policy for Economic Growth and Stability, U.S. Government Printing Office, Washington, D.C., p. 552.

heavy time demand at each step in the process from dreaming up the idea to putting it into military use. In accomplishing these objectives, economic resources are extremely important but cannot be fully substituted for time. Our military budget record since 1950 makes that clear. The large appropriations made after the Korean crisis in fiscal years 1951 and 1952 did not produce a significant expansion in deliveries until 1953 and 1954.

Recent developments abroad have led us to once again want a greatly improved weapons' capability. There is no question that as a nation we want and deserve it. However, as this paper has tried to demonstrate, we cannot get things today just because we want them now. Both the nature of our wants and the administrative processes we use in satisfying them require that in the area of complex equipment like satellites, ballistic missiles, and space flight vehicles, we recognize lead-time and take account of it. A start-then-stop, stop-then-start type of spending policy further complicates the already complex problem of lead-time in military equipment and makes it that much more difficult to fill today's requirements.